Climate change, extremes and their impacts in the Eastern Mediterranean and Middle East

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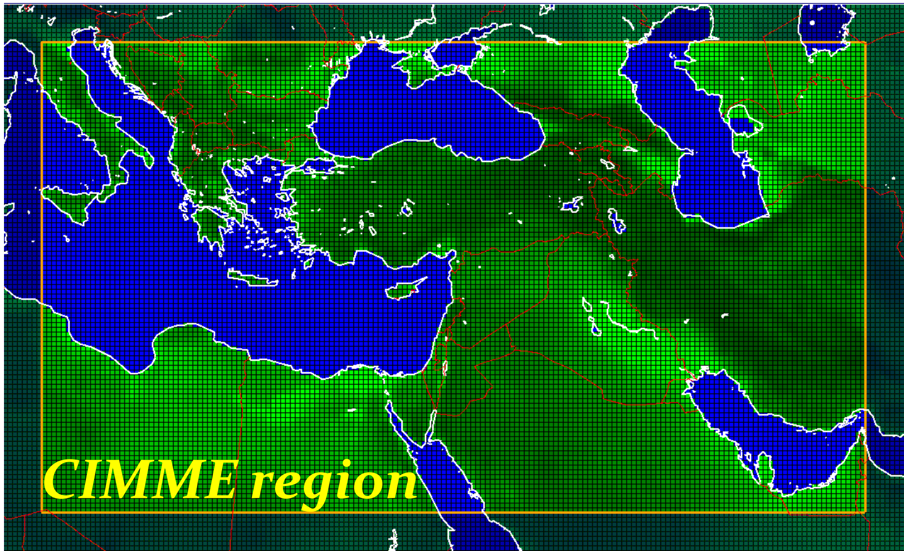
ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ
NATIONAL OBSERVATORY ATHENS

Regional Climate Model Data

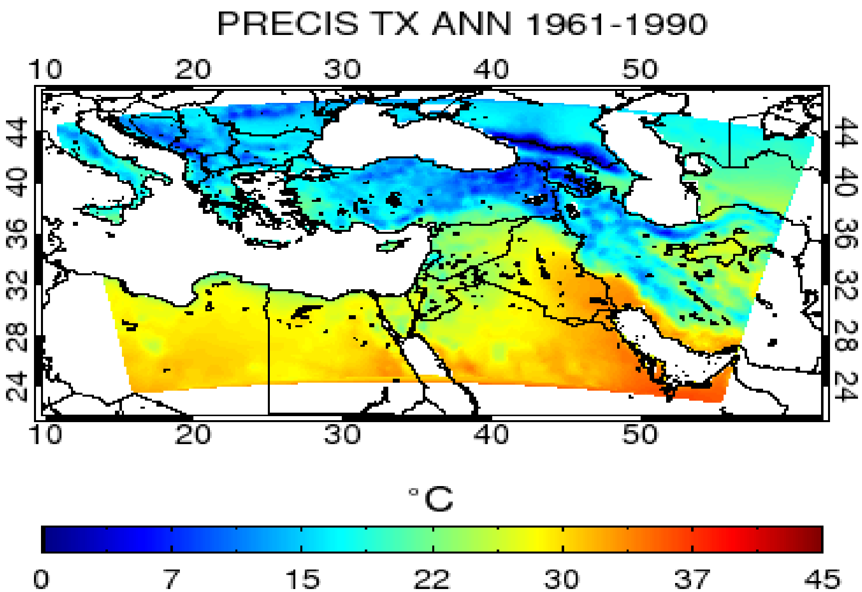
- The daily projections used in the present study, are derived from the PRECIS (Providing Regional Climates for Impact Studies) regional climate model (RCM), based on the UK Met Office Hadley Centre HadRM3P model for the 20th and 21st centuries.
- PRECIS RCM runs were carried out within the framework of the **CIMME** project.
- **CIMME: Climate Change and Impacts in the Eastern Mediterranean and Middle East (EMME)**
- www.cyi.ac.cy/climatechangemetastudy

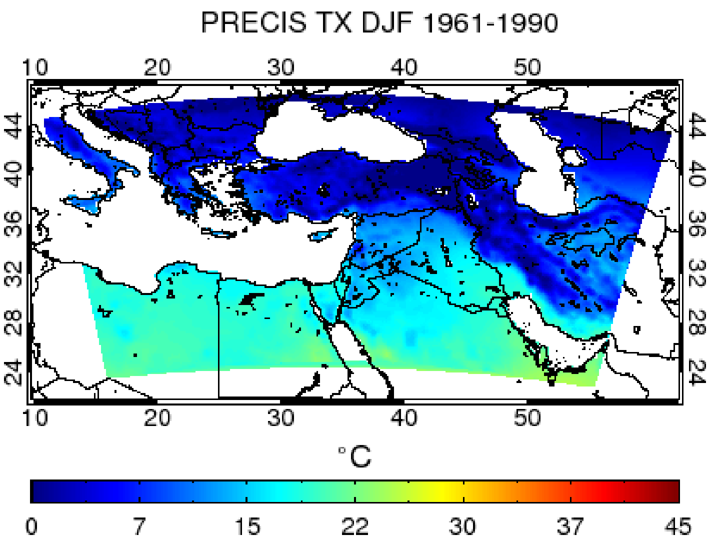
Regional Climate Model Data

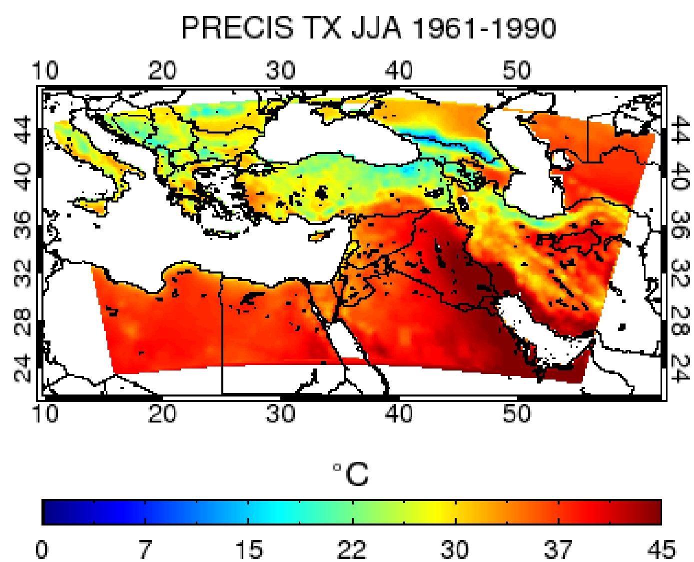
- The PRECIS RCM uses boundary and initial conditions as its parent Atmosphere-Ocean General Circulation Model (AOGCM) HadCM3, employing the IPCC SRES A1B emissions scenario.
- The control run represents the base period 1961-1990 and is used as reference for comparison with future projections.
- Three future time slices are studied: 2010-2039, 2040-2069 and 2070-2099.



Climate of the recent past – TX





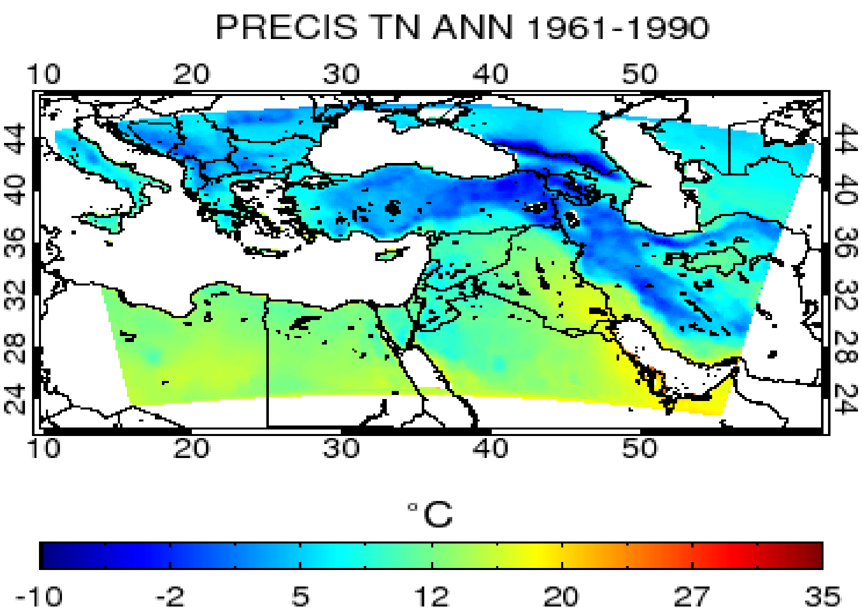


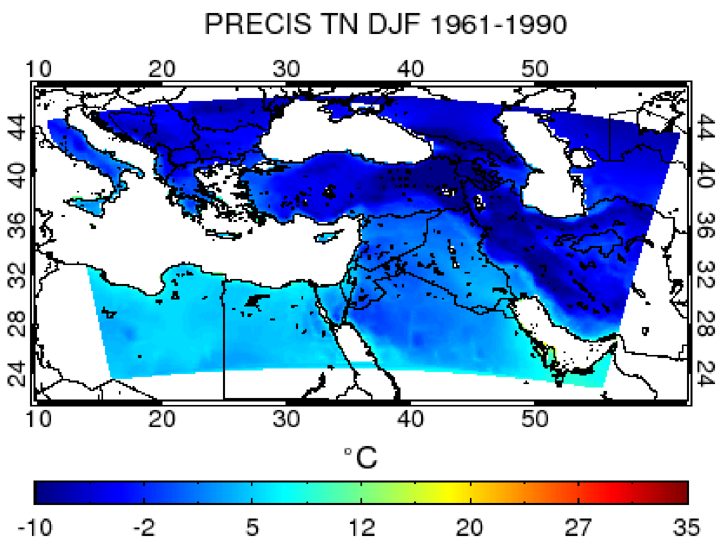
The **annual** average TX ranges from less than 10°C at locations at latitudes of 36°N and above, up to 35°C in continental sites of the Arabian Peninsula.

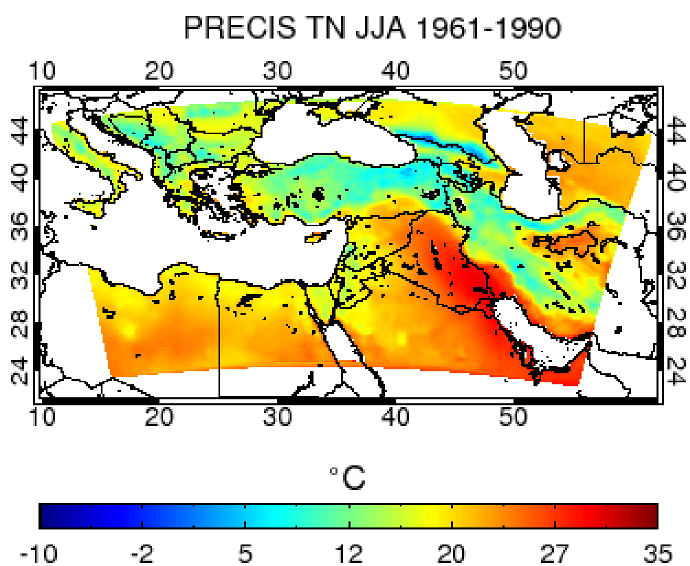
WINTER: TX approximates 10 °C in the north, while it reaches 25°C in North Africa and the Arabian Peninsula.

SUMMER: in the northern parts TX approximates 22°-30°C. Very hot summer conditions, with TX exceeding 40°C, appear in the Middle East and North Africa.

Climate of the recent past - TN







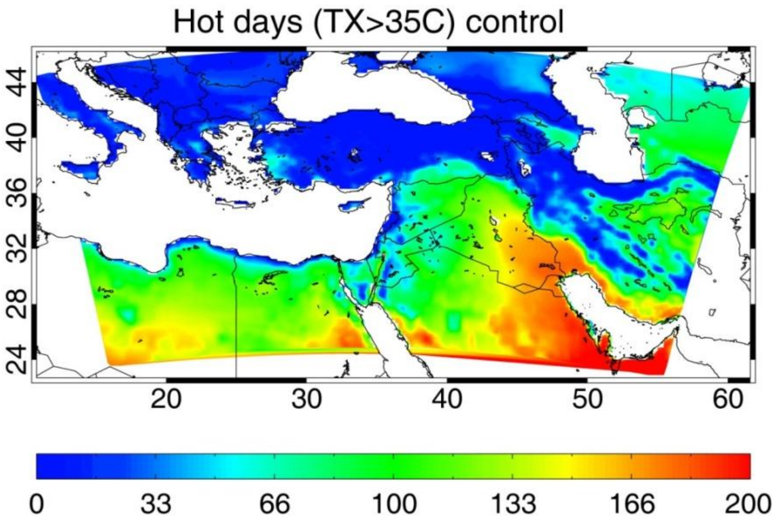
The **annual** rates of TN vary from -10 to 20°C.

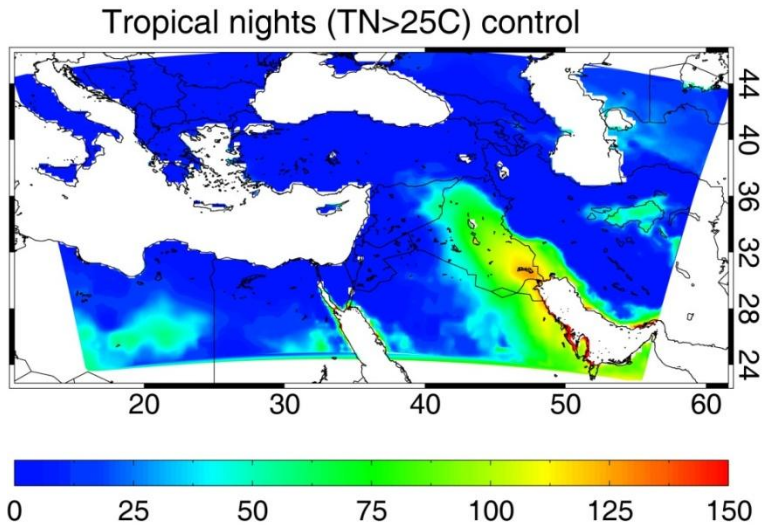
WINTER: Sub-regions at elevated locations in the north show TN of –10°C, while positive TN values indicate the mild climates of low-altitude coastal areas of the Mediterranean as well as the sub-tropical regions.

Latitudinal and altitude-related differences are larger and more variable regarding summer minimum temperature.

During **SUMMER** TN in the northern domain ranges between 10° and 18°C, while in the south it is 20°C and higher.

Climate of the recent past – T$_{emp}$ indices

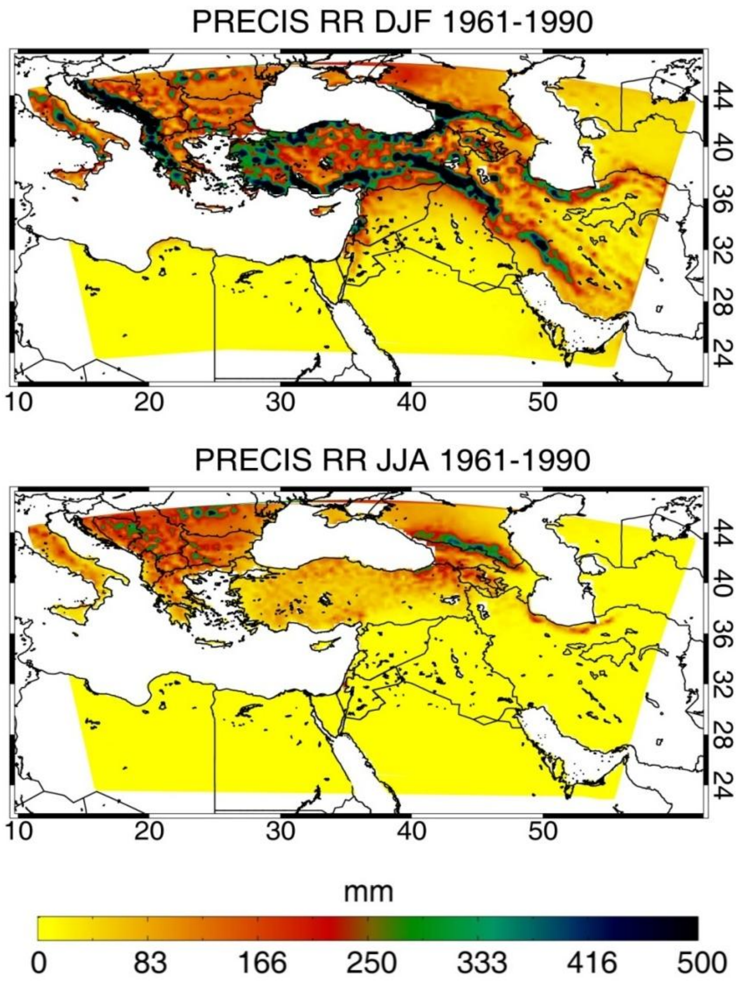




Hot days: the meridional gradient is very steep around 36°-38°N.
In the northern part of the EMME region the number of very hot days is less than a month/year. In contrast, in the southern part of the domain extended heat periods, i.e. 3-6 months/year with TX>35°C are common.

Tropical nights appear to occur during one month or less per year in the northern EMME.
In the south this is typically 1-2 months and up to more than 4 months per year around the Persian Gulf.

Climate of the recent past – RR

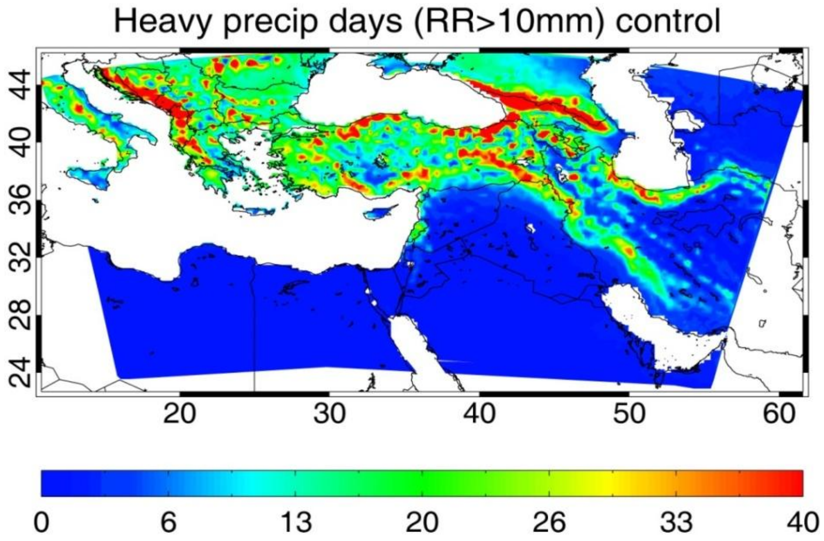


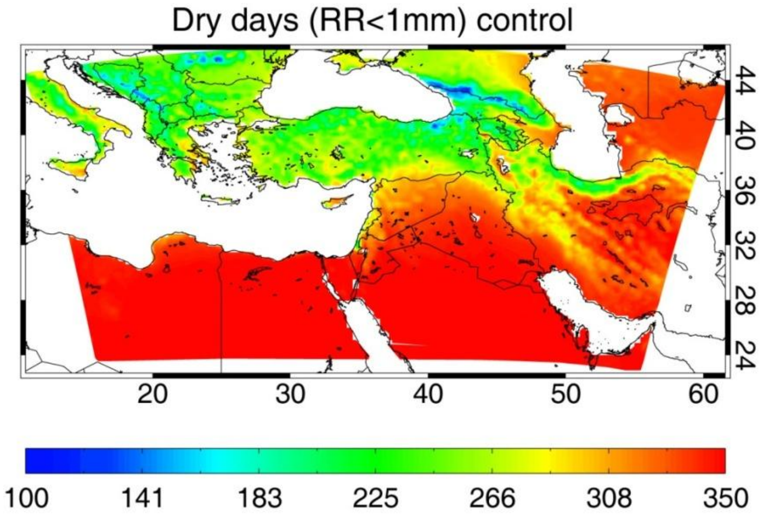
WINTER: The overriding influence of local topography is evident in the high winter precipitation amounts which are recorded in the windward (exposed to moist air masses) slopes on the western coast of Balkans (approximately 500 millimetres).

Higher elevations in Turkey are seen to receive large precipitation amounts, while smaller amounts falling further inland in the Balkan region and even less in the southern parts of the study domain.

SUMMER: Dry season for major part of the study region.
The Balkan region receives most of the summer rainfall of the domain, owing to convective thunderstorms, which contribute significant amounts to summer rainfall over much of the European region.

Climate of the recent past – RR indices





Heavy precipitation: Along the western edge of the Balkan Peninsula and other high-elevation areas, e.g. in the Caucasus, heavy precipitation occurs about 40 days per year.

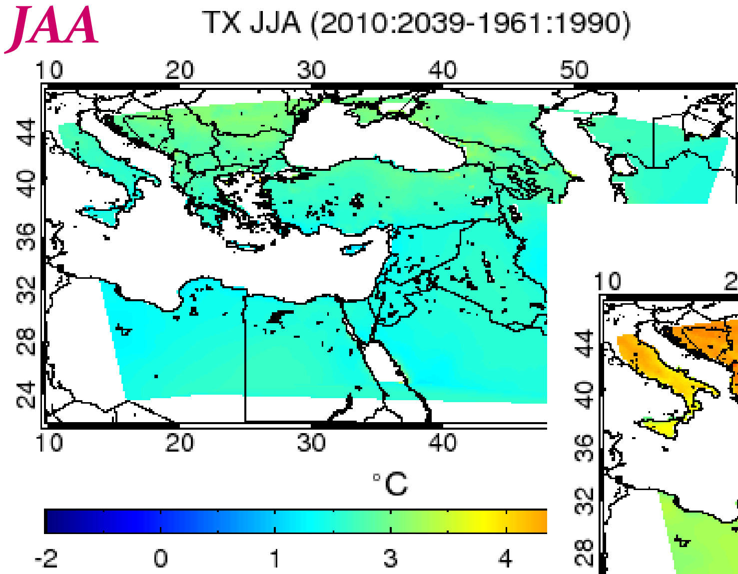
Number of dry days:

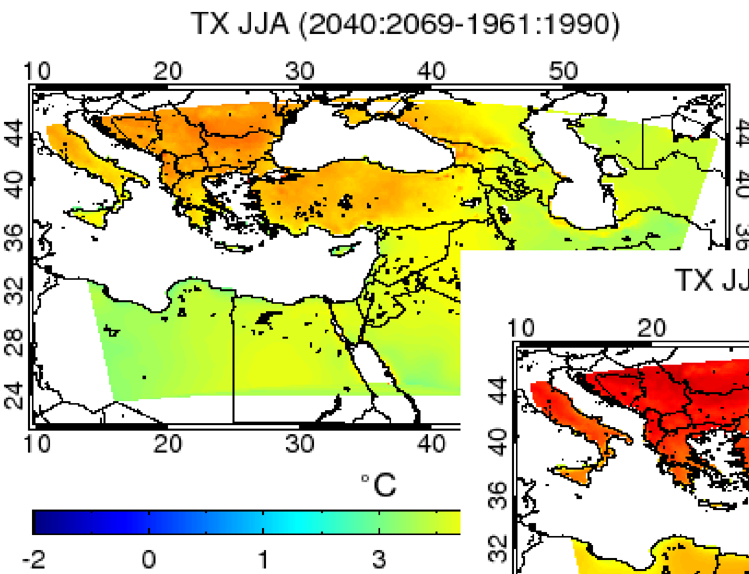
• The wet regions show fewest dry days, i.e. 160 to 200 per year, while in lower-elevation and northern coastal Mediterranean regions this ranges between 250 and 300 per year.

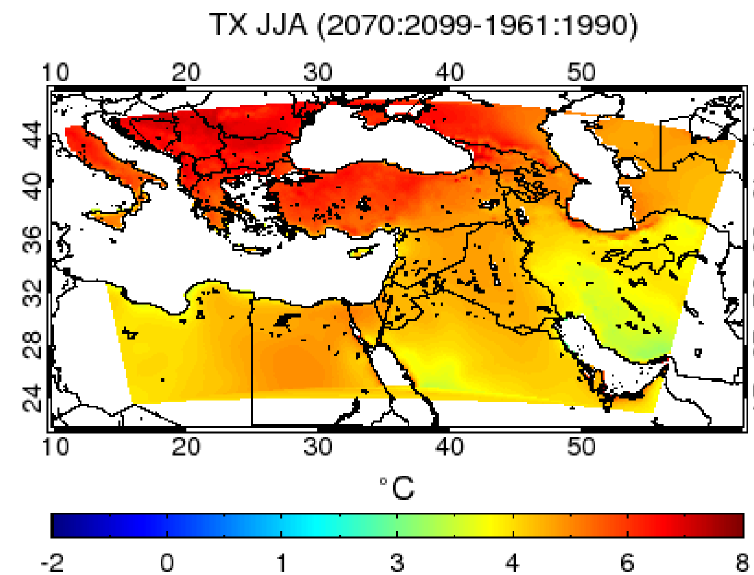
• The driest areas are located in the southern EMME, with up to 300 dry days per year in several countries of the Middle East, e.g. Israel and Syria, up to a year in the desert areas of Egypt, Saudi Arabia and southern Iraq

Future Climate– TX

JAA





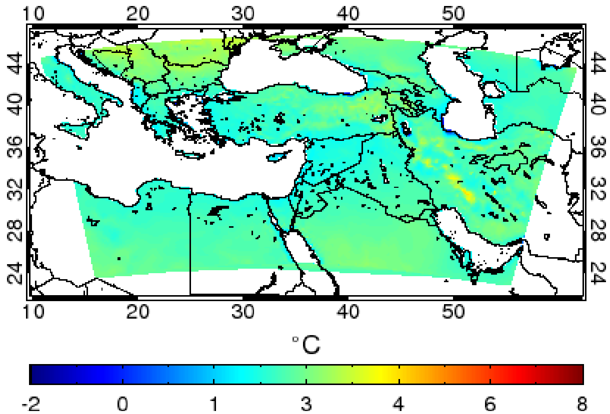


The regional warming will be gradual, both of TX and TN, ranging from 1-3°C in the near-future (2010-2039), to 3-5°C in the mid-century period (2040-2069) and 3.5-7°C by the end of the century (2070-2099).

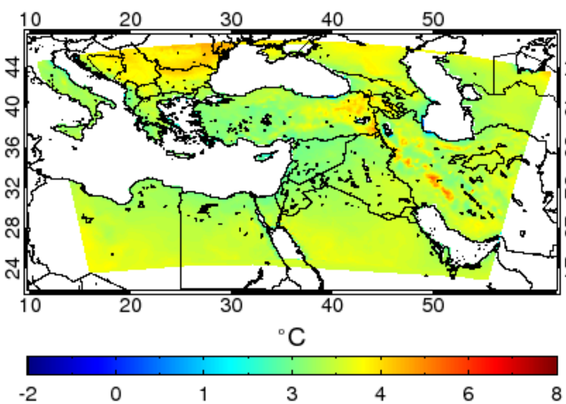
Future Climate– TN

DJF

TN DJF (2040:2069-1961:1990)

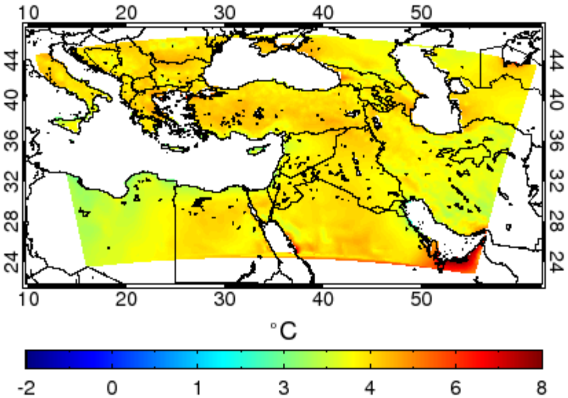


TN DJF (2070:2099-1961:1990)

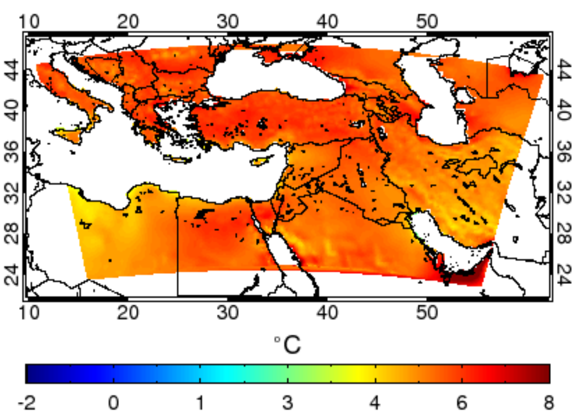


JAA

TN JJA (2040:2069-1961:1990)



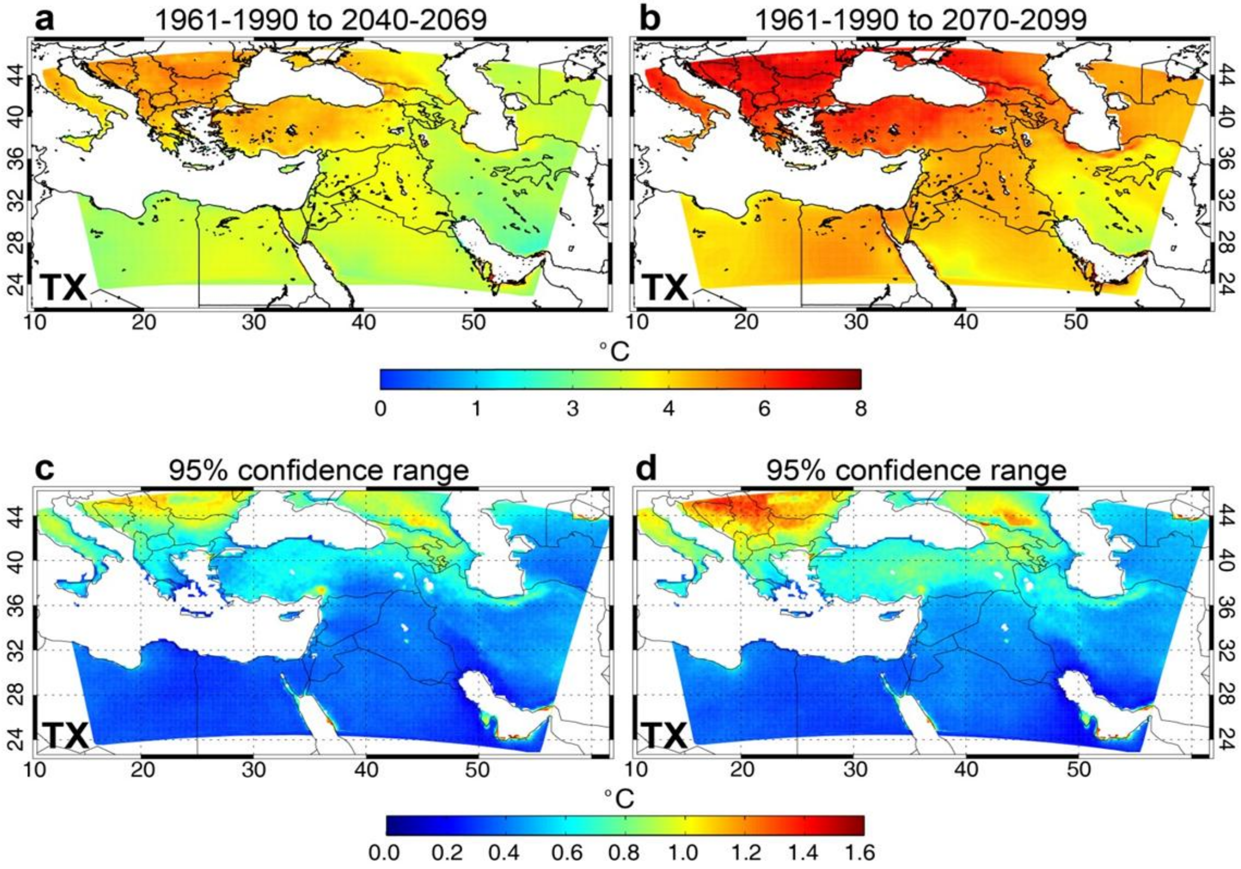
TN JJA (2070:2099-1961:1990)



The warming is more spatially uniform for winter TN.

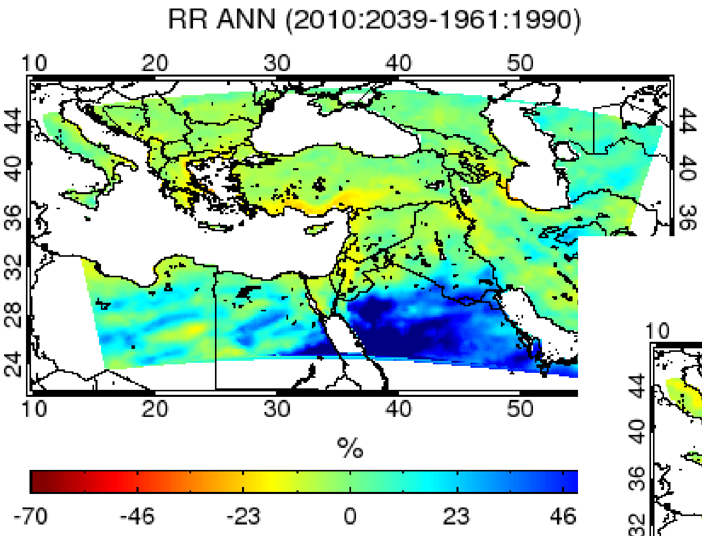
The stronger warming tendency of summer TN (especially in the end-of-century period) highlights the <u>exceptional warming expected</u> in the EMME region.

Confidence ranges TX



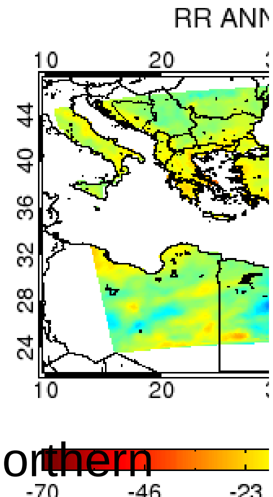
We are 95% confident that the rise in TX by the end of the century will be between 3.5±0.4 in southern Iran and 7±1.3°C in the northern Balkan region, i.e. varying with subregion, indicating an uncertainty of about 15% (similar for TN).

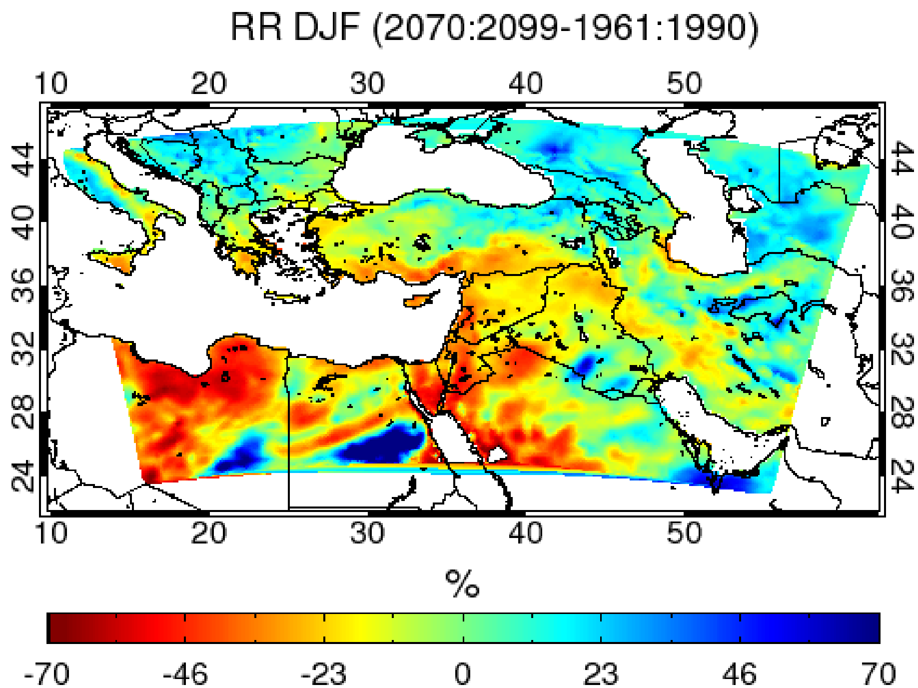
Future Climate– RR



The strongest drying is projected around the eastern Mediterranean and North Africa:

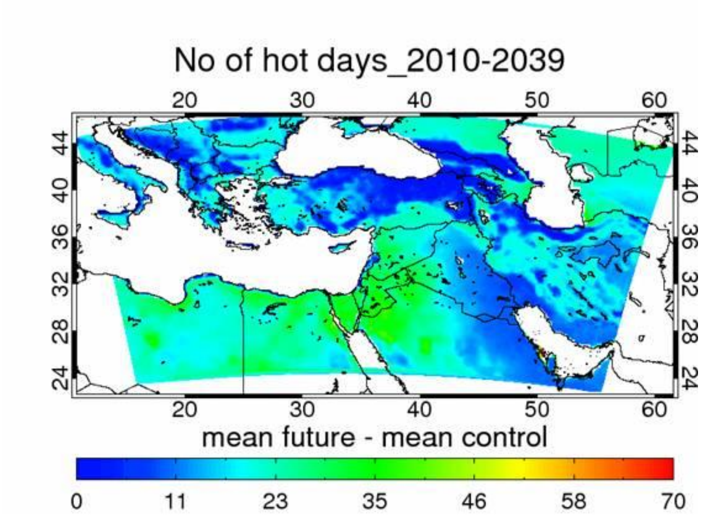
- ⇨ –10% to –25% in 2010-2039
- ⇨ –20% to –35% in 2040-2069
- ⇨ –30% to –50% in 2070-2099.

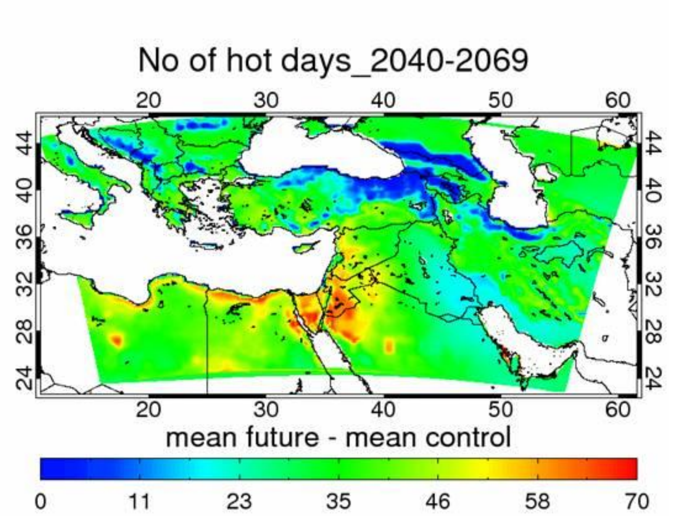


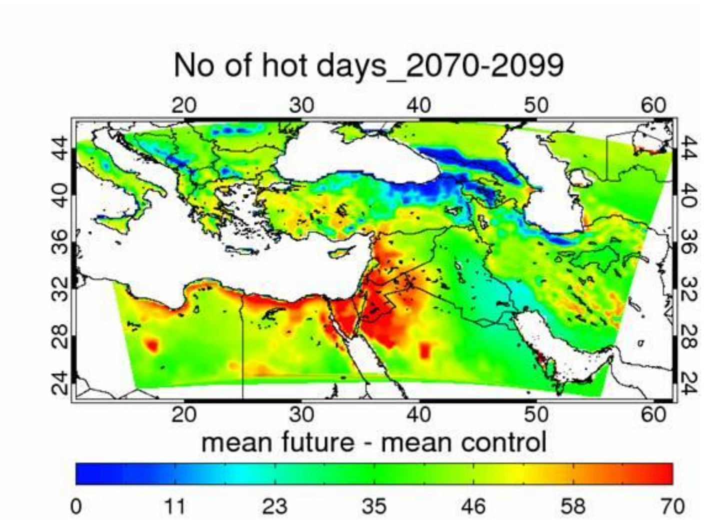


Western Italy, the Balkans, northern Turkey and the Caucasus may become wetter in winter probably related to the increased evaporation from the surrounding water bodies.

Future Climate– Temp indices





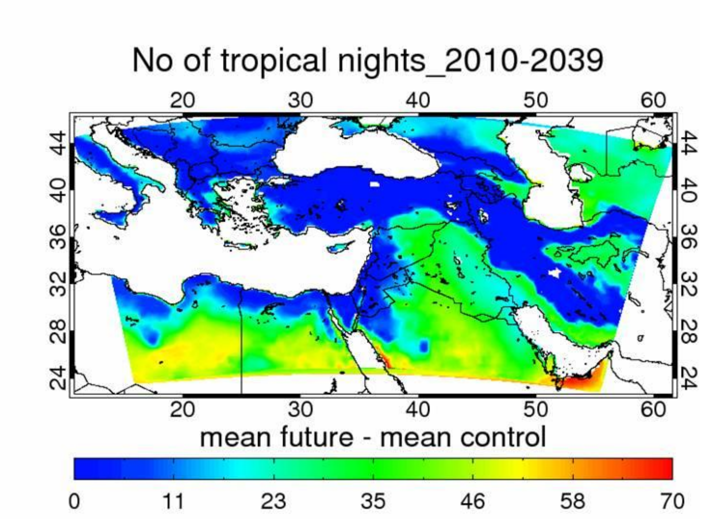


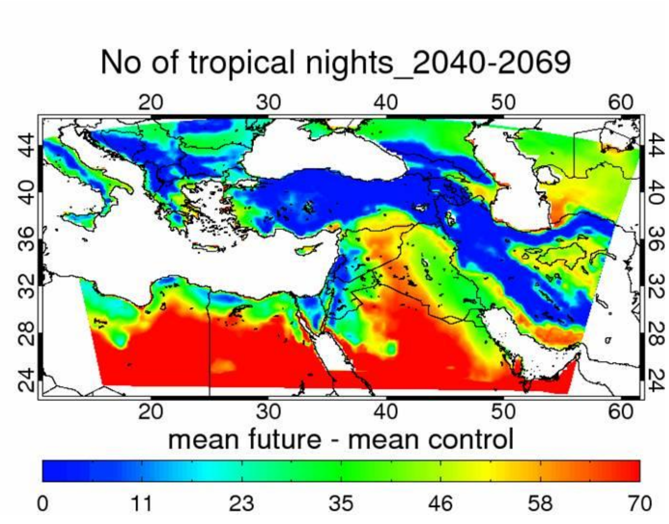
The changes of the numbers of hot days per year are positive throughout the EMME and remarkably large and statistically significant in all periods.

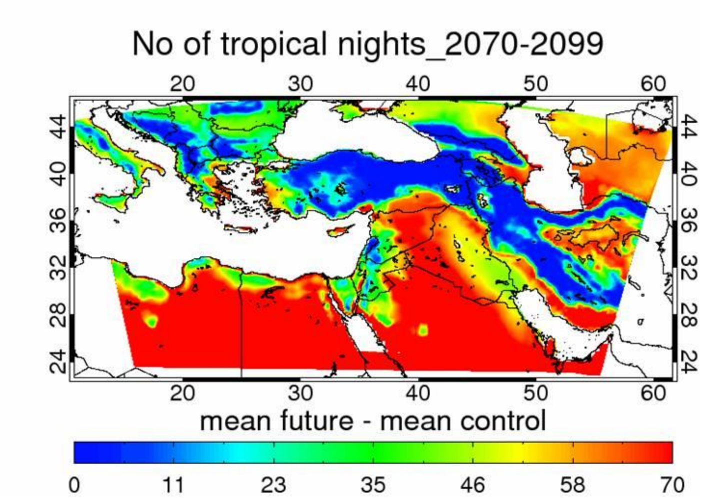
By the end of the century the index increases by 0-15 days over the higher elevation areas and by 20-40 days for most of the domain.

The strongest increase (more than 2 months) appears over the Levant and the North African coast, approaching the conditions experienced in the Gulf region during the reference period.

Future Climate– Temp indices

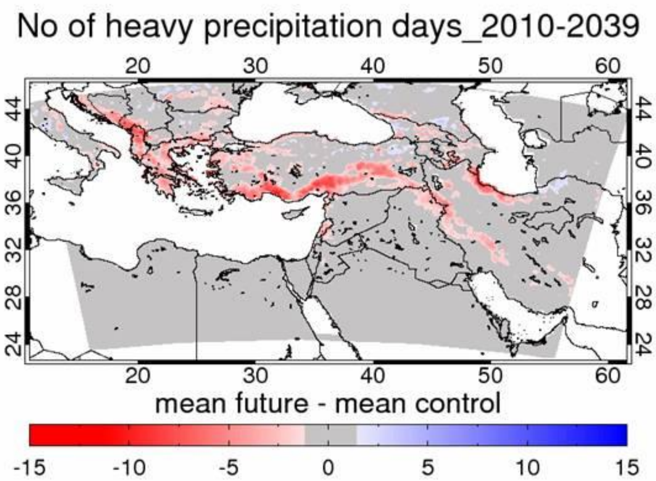


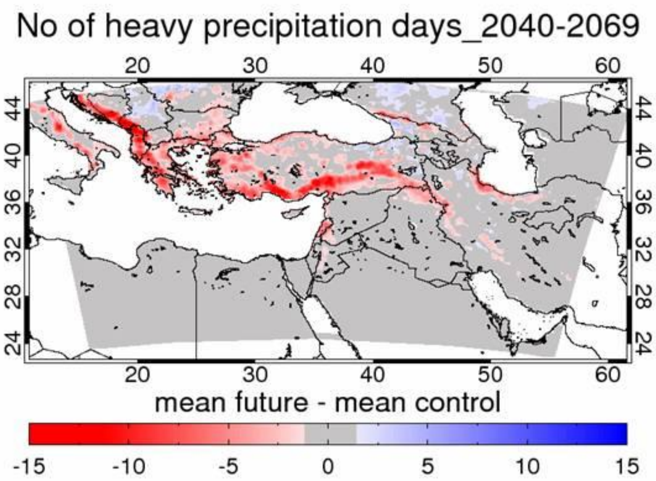


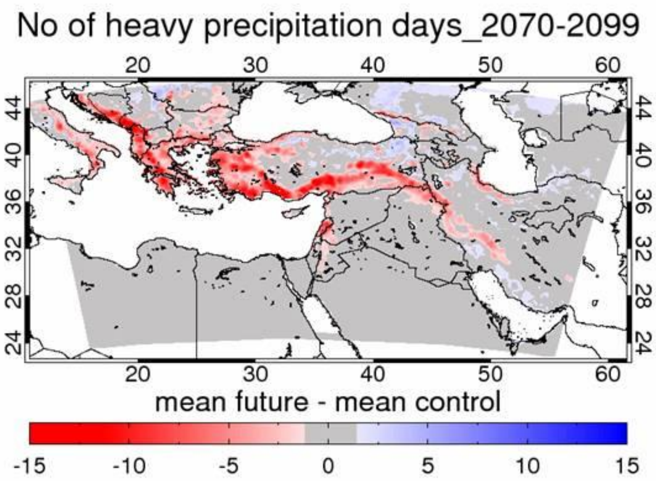


A gradual future increase is predicted, starting in the south of the EMME and progressing north, increasing by almost a month at the low-elevation areas of the Balkans, the Levant, the North African coast and southern Iran, and by two months and more in the southeastern part of the region

Future Climate– RR indices

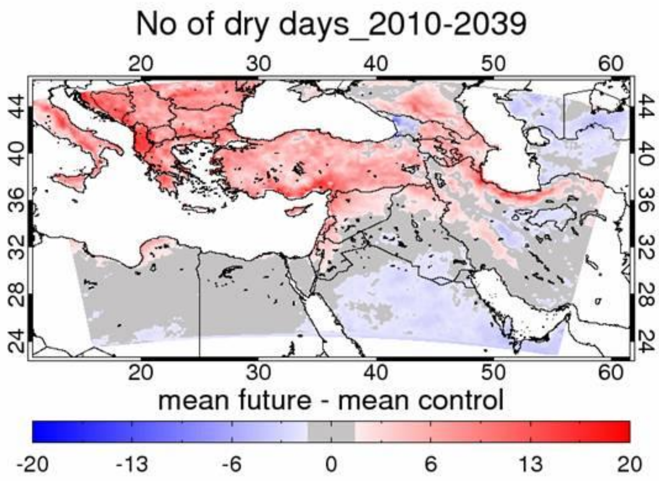


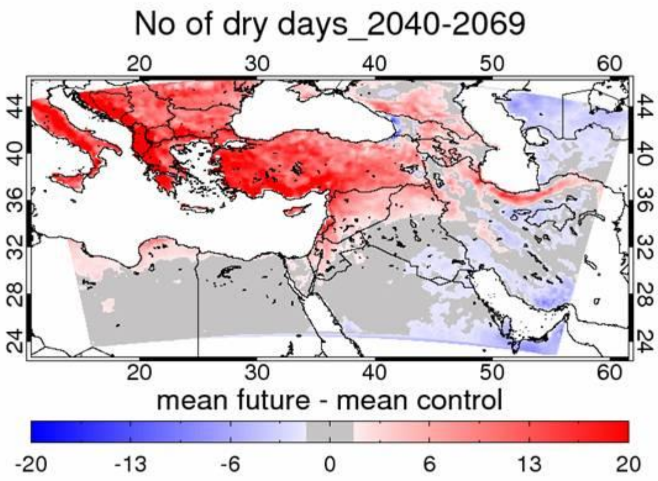


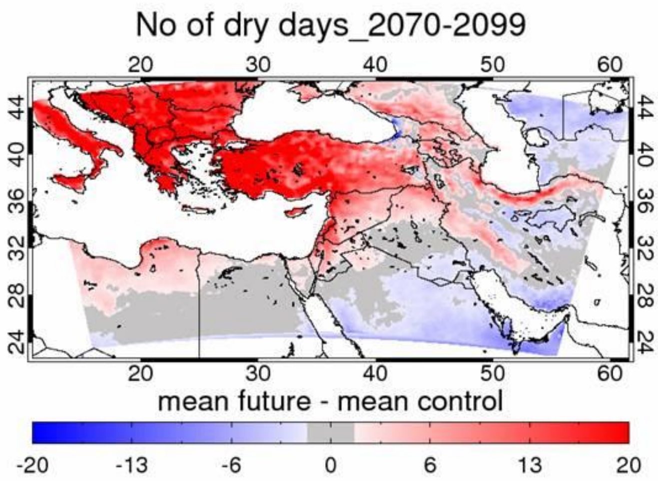


The number of days with heavy precipitation (>10 mm/day) is expected to decrease in the high-elevation areas of EMME (typical locations for experiencing such events during recent climate conditions).

Future Climate– RR indices



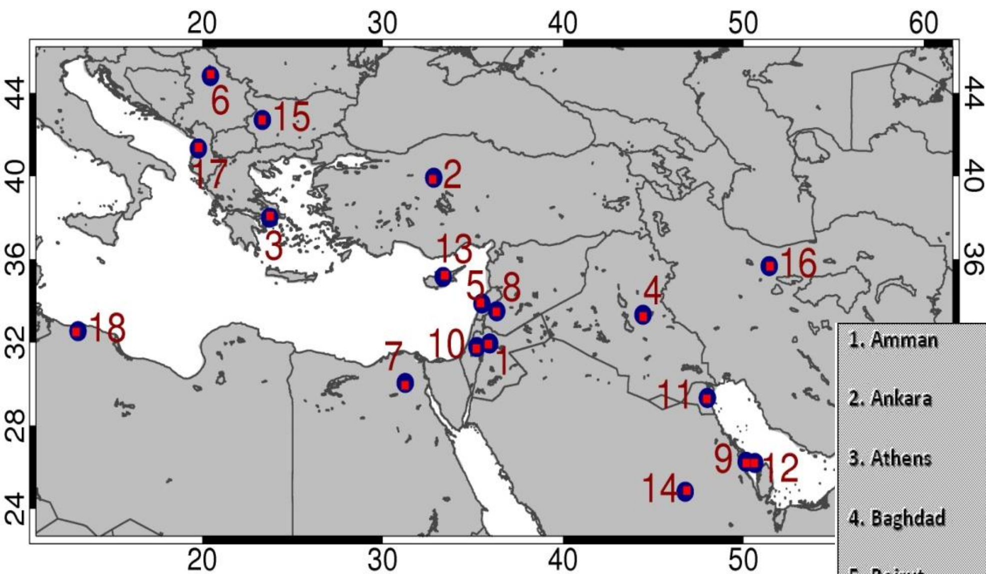




The number of dry days is expected to increase in the northern (wetter) areas of EMME at rates of:

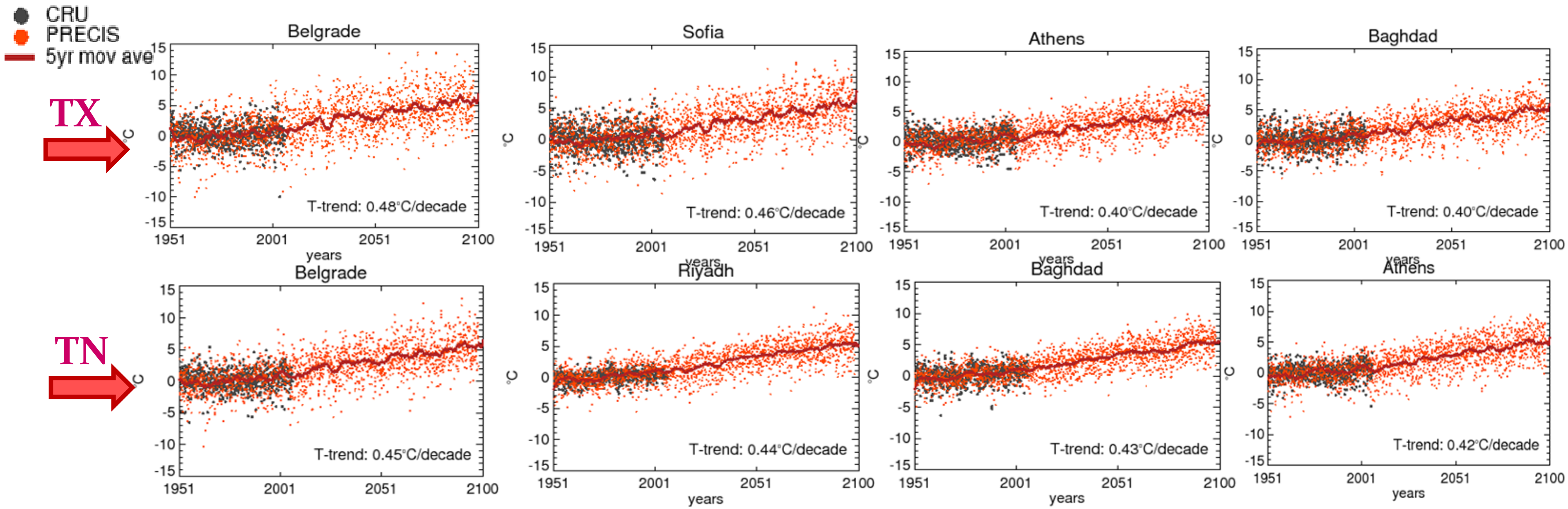
⇨ 5 to 15 more days in 2010-2039
⇨ 10 to 20 more days in 2040-2069
⇨ > 20 more days in 2070-2099

Trend analysis of long-term temperature time series at 18 cities in the study area over the period 1901-2100.



1. Amman	35.93 °E	31.95 °N	7. Cairo	31.25 °E	30.05 °N	13. Nicosia	33.35 °E	35.15 °N
2. Ankara	32.83 °E	39.92 °N	8. Damascus	36.32 °E	33.50 °N	14. Riyadh	46.77 °E	24.82 °N
3. Athens	23.73 °E	38.00°N	9. Dhahran	50.15 °E	26.26 °N	15. Sofia	23.33 °E	42.70 °N
4. Baghdad	44.43 °E	33.33 °N	10. Jerusalem	35.22 °E	31.78 °N	16. Tehran	51.43 °E	35.67 °N
5. Beirut	35.50 °E	33.87 °N	11. Kuwait	48.00 °E	29.33 °N	17. Tirana	19.78 °E	41.33 °N
6. Belgrade	20.45 °E	44.81 °N	12. Manama	50.63 °E	26.20 °N	18. Tripoli	13.11 °E	32.54 °N

Future Climate–Trends TX

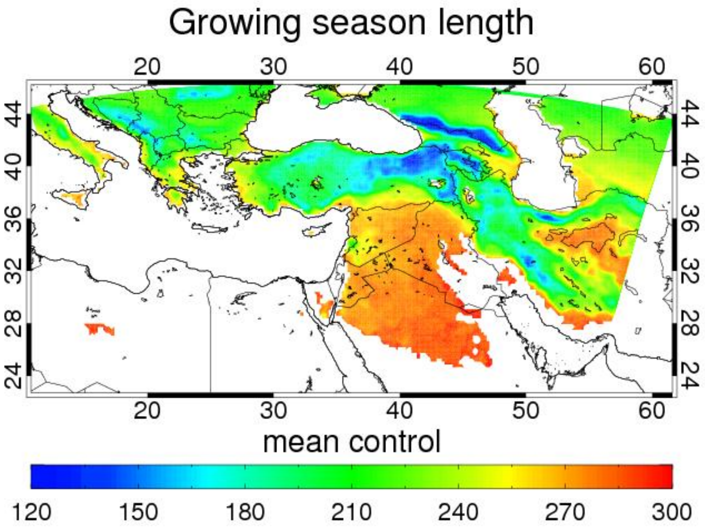


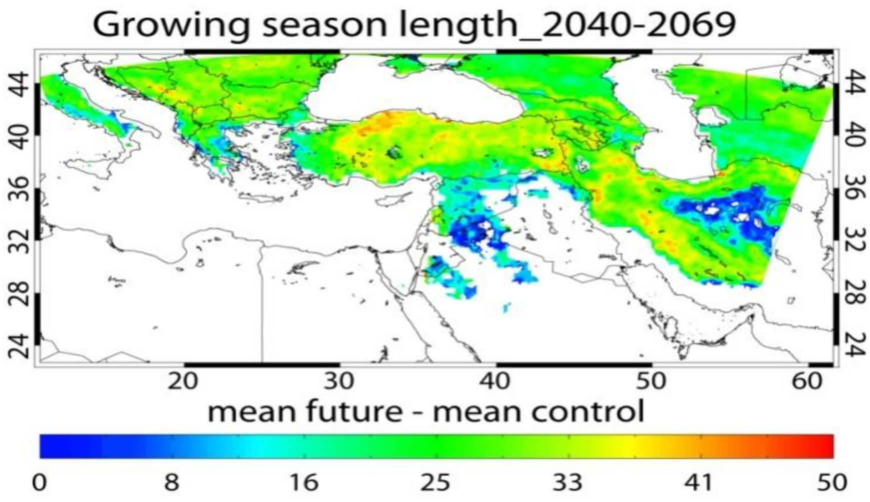
TX: larger increasing trends are found in Belgrade, Sofia and Ankara with trends of the order of 0.48, 0.46 and 0.44°C per decade respectively. Maximum temperatures in Amman, Athens and Baghdad are found to increase by 0.40°C per decade.

TN: large positive trends exceeding 0.40°C per decade are found for Belgrade, Riyadh, Baghdad and Athens.

For at least half of the study sites TN trends are found to be larger compared to those related to TX and TM (e.g. Athens, Baghdad, Cairo, Dhahran, Jerusalem, Kuwait City, Riyadh, Tehran and Tripoli). Most of these sites, already experience high temperatures and are expected to face warmer conditions mainly due to increases in minimum temperatures.

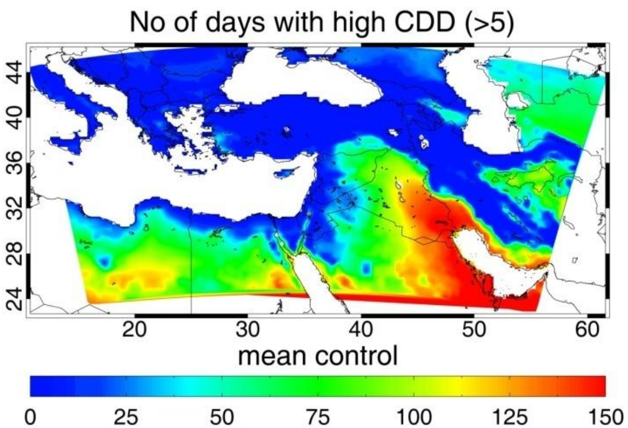
Impacts– Agriculture

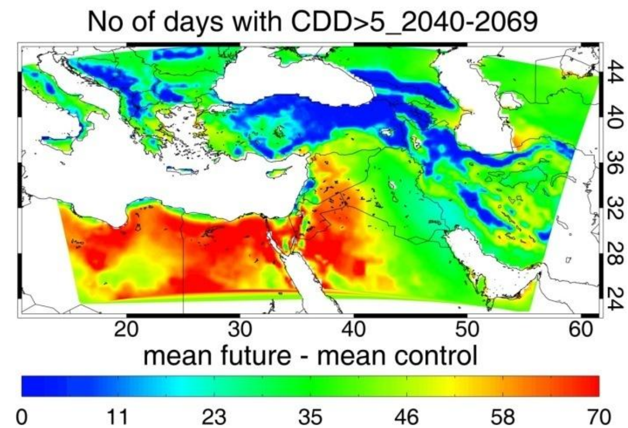




We used the PRECIS output to calculate the growing season length, defined as the number of days between the last spring frost and the first autumn frost (frost-free areas appear white in figure). The model results indicate that by mid-century the length of the growing season may increase by about one month/year in Turkey, the Balkans and part of Iran. This does not necessarily translate to an increase in crop yields since rain deficits and heatwaves can lead to agricultural losses.

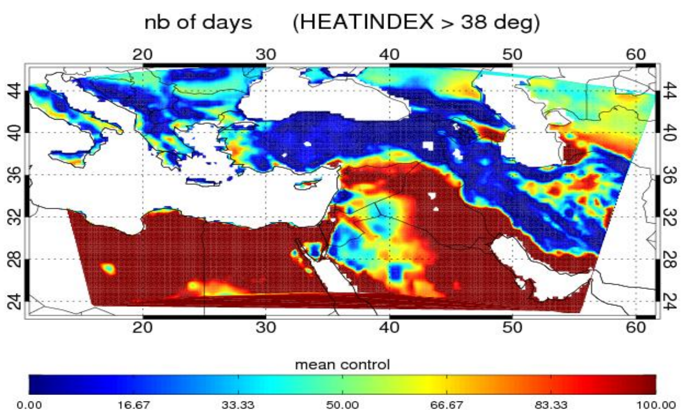
Impacts– Cooling energy requirements

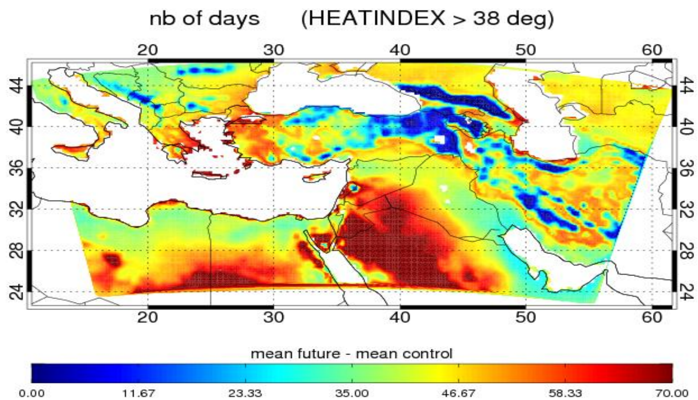




An illustrative view of the increasing cooling demands in the region is provided by the mean number of days/year during which cooling will need to exceed 5°C (CDD>5°C), comparing the control and mid-century periods. It indicates the additional strong cooling needed to provide comfortable living conditions and cope with heat waves. Left Figure shows that during the control period the no of days with CDD>5°C in the northern and coastal parts is typically less than a few weeks to one month, while this is 2-3 months in the southern desert areas and up to 5 months around the Gulf. The projected change in the 2040-2069 period appears to be quite drastic, with 3-6 weeks in the northern and coastal areas, one month around the Gulf, up to 2 months in parts of Syria, southern Israel, Jordan, parts of Saudi Arabia, Egypt and Libya.

Impacts– Population Discomfort





Heat effects on human comfort (or discomfort) is assessed by computing the humidex, an index employed to express the temperature perceived by people. In the control period, most parts of Greece and Western Turkey have around a month of thermal discomfort days for the population. This value reaches 3 or more months for North Africa and south parts of the Arabian peninsula. Interestingly, coastal and island regions are equally vulnerable. Coastal regions in the Eastern parts of Greece, Crete, western/central Turkey and Cyprus, the duration of the period with humidex>38^{o}C is projected to increase by as many as 50 days in 2040-2069.Even larger increases of 70 days are projected for the Arabian peninsula. This parameter shows smaller changes in mountainous areas (eg. Balkans, Anatolia) i.e. their cool summer climate should be maintained.

Conclusions

- The analysis of data for the 20th and the 21st century with an RCM (PRECIS), based on the A1B scenario of the IPCC, suggest substantial regional climate changes in the EMME region.

- The PRECIS results indicate a continual and gradual future warming, being strongest in the north.

- In comparison with the reference period (1961-1990) the mean temperature (TM) rise over land within the EMME will be about 1-3°C in the near-future (2010-2039), 3-5°C by mid-century (2040-2069) and 3.5-7°C by the end-of-century (2070-2099).

- The mean temperature trend over the period 1950-2100, with a focus on capital cities in the EMME, is about 0.37±0.9°C/ decade. This suggest that the region warms much more strongly than the global mean of 2.8°C (with a range of 1.7-4.4°C) until the end of the century – estimated relative to pre-industrial conditions – projected by the IPCC (2007) for the A1B scenario.

Conclusions

- The projected warming is approximately spatially uniform for nighttime minimum temperatures (TN), whereas the increase of maximum daytime temperatures (TX) is more rapid in the north, e.g. the Balkans and Turkey, than in the south.
- Hot conditions that occurred only rarely in the reference period may become the norm by the middle and the end of the century, which will be associated with heat waves, the type of weather extreme with most casualties.
- The coolest summers during the period 2070-2099 may actually be warmer than the hottest ones during 1961-1990.
- Climate change in the region will have important negative consequences for humans and ecosystems, especially due to heat stress and reduced water resources; and population growth and economic development may aggravate the situation.
- Increasing dryness in the EMME will likely be associated with fire activity and consequent pollution emissions.
- The region has many large cities, including several megacities in which air quality is seriously degraded (e.g. Cairo, Tehran).

Conclusions and suggestions

- It is expected that the annual precipitation will typically decline by 5-25% in 2040-2069 and 5-30% in 2070-2099 relative to the reference period 1961-1990.

- The drop will be particularly large (>15%) in Cyprus, Greece, Israel, Jordan, Lebanon, the Palestine territories and Syria.

- The region will need to invest in desalination to counteract these tendencies.

- The energy use for air conditioning will grow in parallel with water deficits, which additionally distresses energy production through the demand for desalination; and the competition with other sectors in need of water will increase.

- On the other hand, the heating requirements during winter will decrease in the northern part of the region, which moderates the overall increase in energy consumption and associated pollution emissions. However, these compensating changes occur in different countries and seasons, and will not alleviate the need for extensive cooling during summer.

Climate Indicators for Athens

► Athens, is a large metropolitan city surrounded by mountains, susceptible to air pollution episodes during periods of anticyclonic circulation, prone to heat waves in the summer and floods during heavy precipitation events.

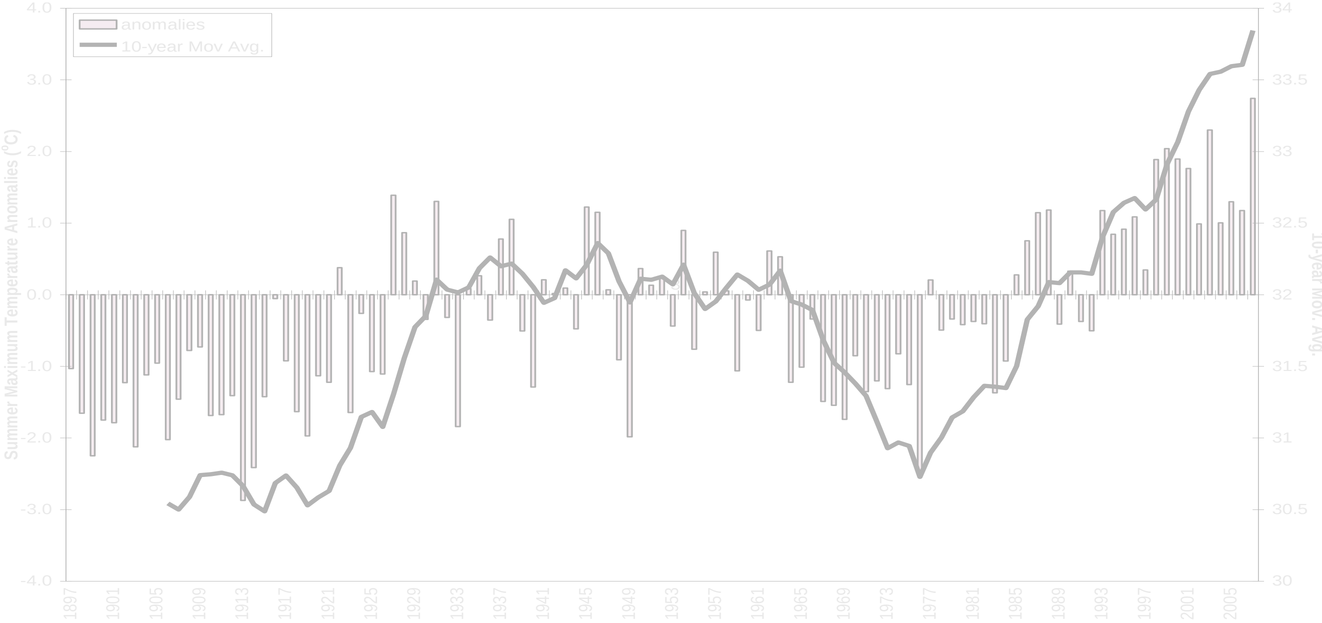
Climate indicators chosen to represent observed climate hazards in Athens:

- ► Maximum temperature on an annual and seasonal (summer) basis
- ► The number of hot days/nights
- ► Monthly and annual total rainfall
- ► Urban Heat Island based on difference between urban and rural temperatures (derived from model simulations)

► The 100+ year-long surface air temperature and rainfall record of the National Observatory of Athens (NOA) has been used.

Summer TX

Athens: 1897-2006

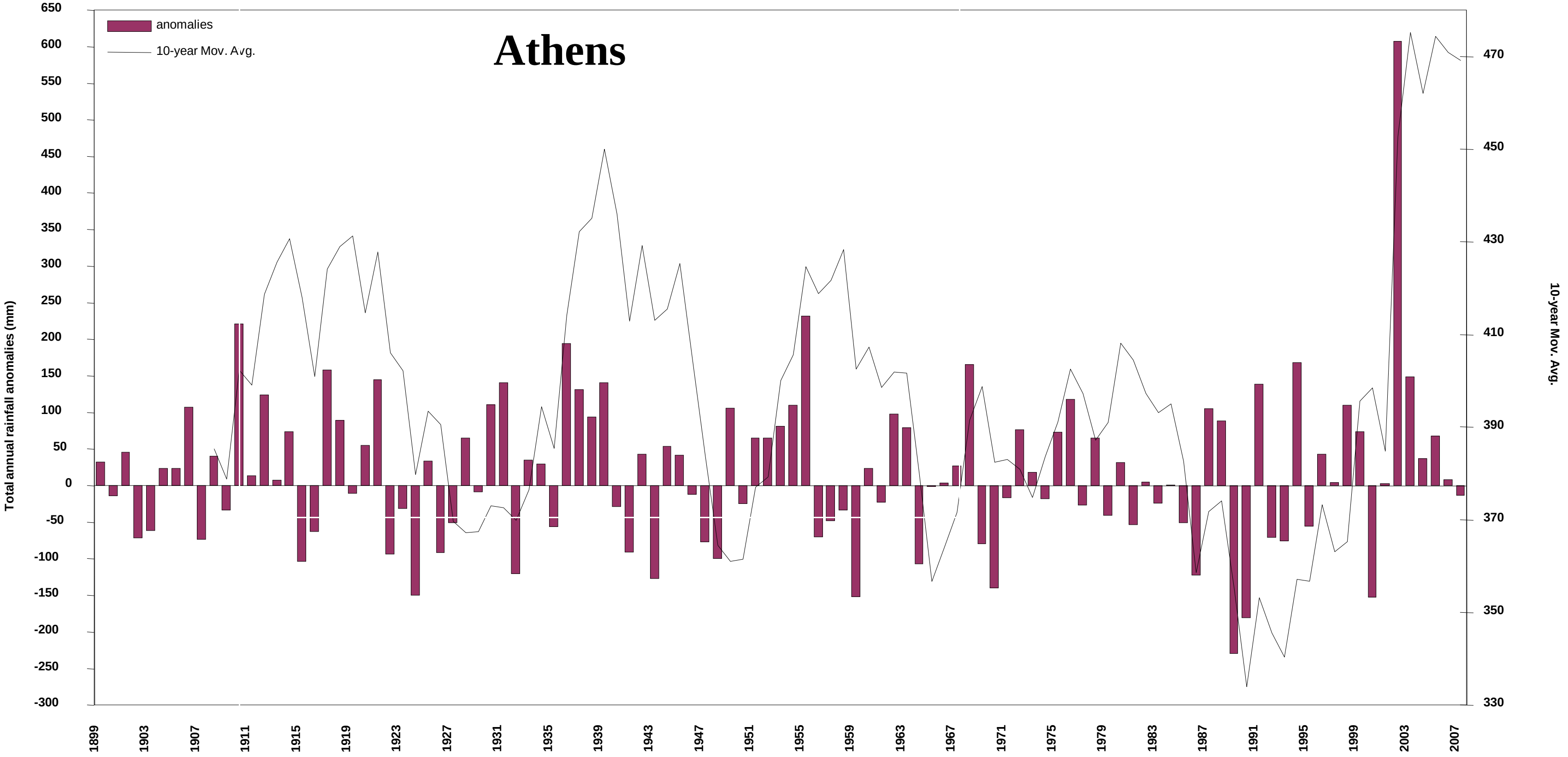


Temperature:

•the main feature of the summer **maximum temperature** is a marked rise evident from the 1970s

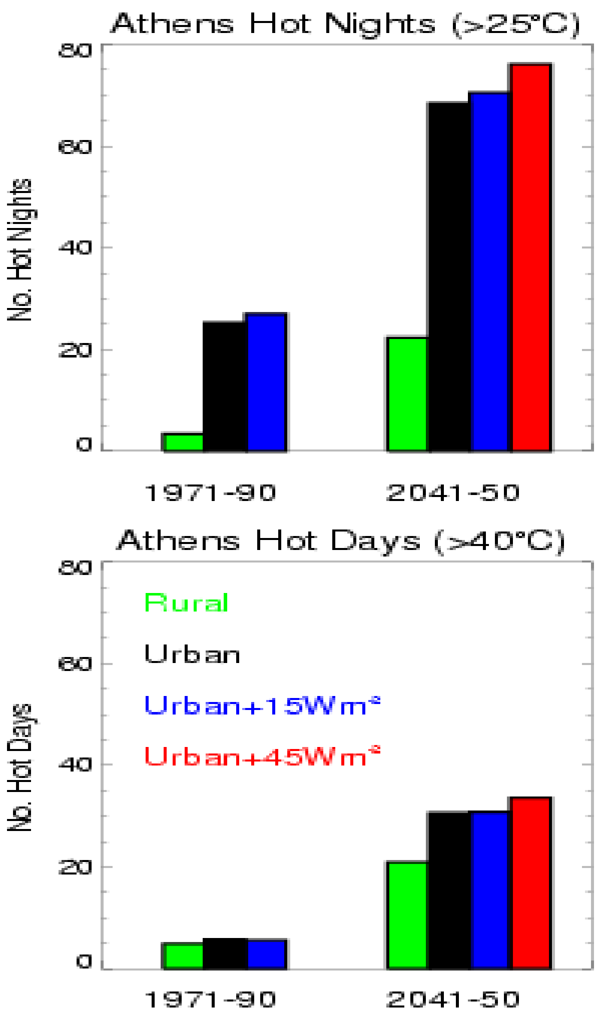
•a clear positive linear trend in the **number of hot days** over the data records for Athens, more evident from the mid-1970s onwards

Annual Rainfall



►Rainfall amounts do not exhibit a statistically significant trend

The urban heat island in Athens



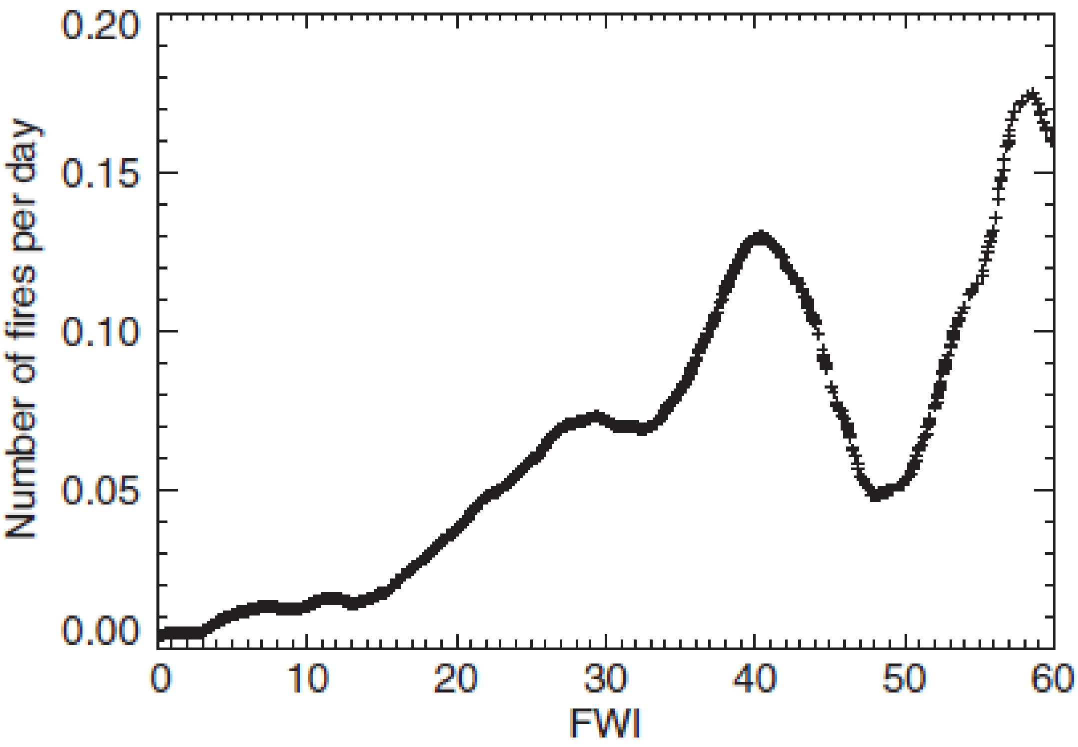
►Athens exhibits a much more intense heat island for minimum temperatures

Vulnerability indicators for Athens

- Peri-urban fires
- Health & Well-being
- Energy Consumption
- Air pollution-Ozone exceedance

Fire Weather Index (FWI)

➢Peri-urban fires highly sensitive to climate change, since fuel moisture is affected by precipitation, relative humidity, air temperature and wind speed



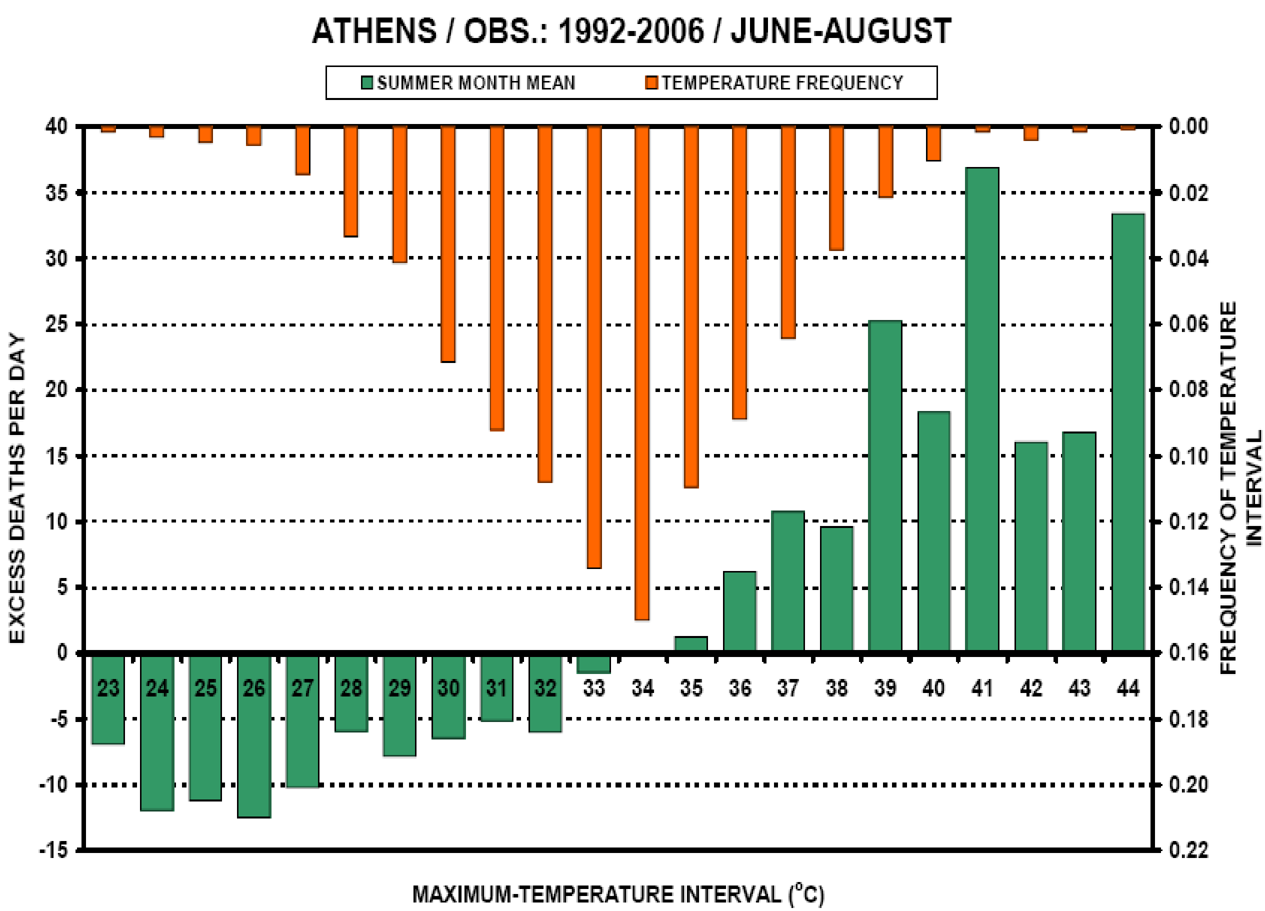
Mean number of fires per day against FWI for fires near Athens

▪The required inputs are: daily maximum temperature, relative humidity, wind, and precipitation

▪The threshold for daily fire occurrence is around **FWI=15**, while there is low fire risk for FWI < 15

Health: All cause daily mortality

➢The study of the relation between climate hazards and mortality is useful for healthcare and civil protection planning

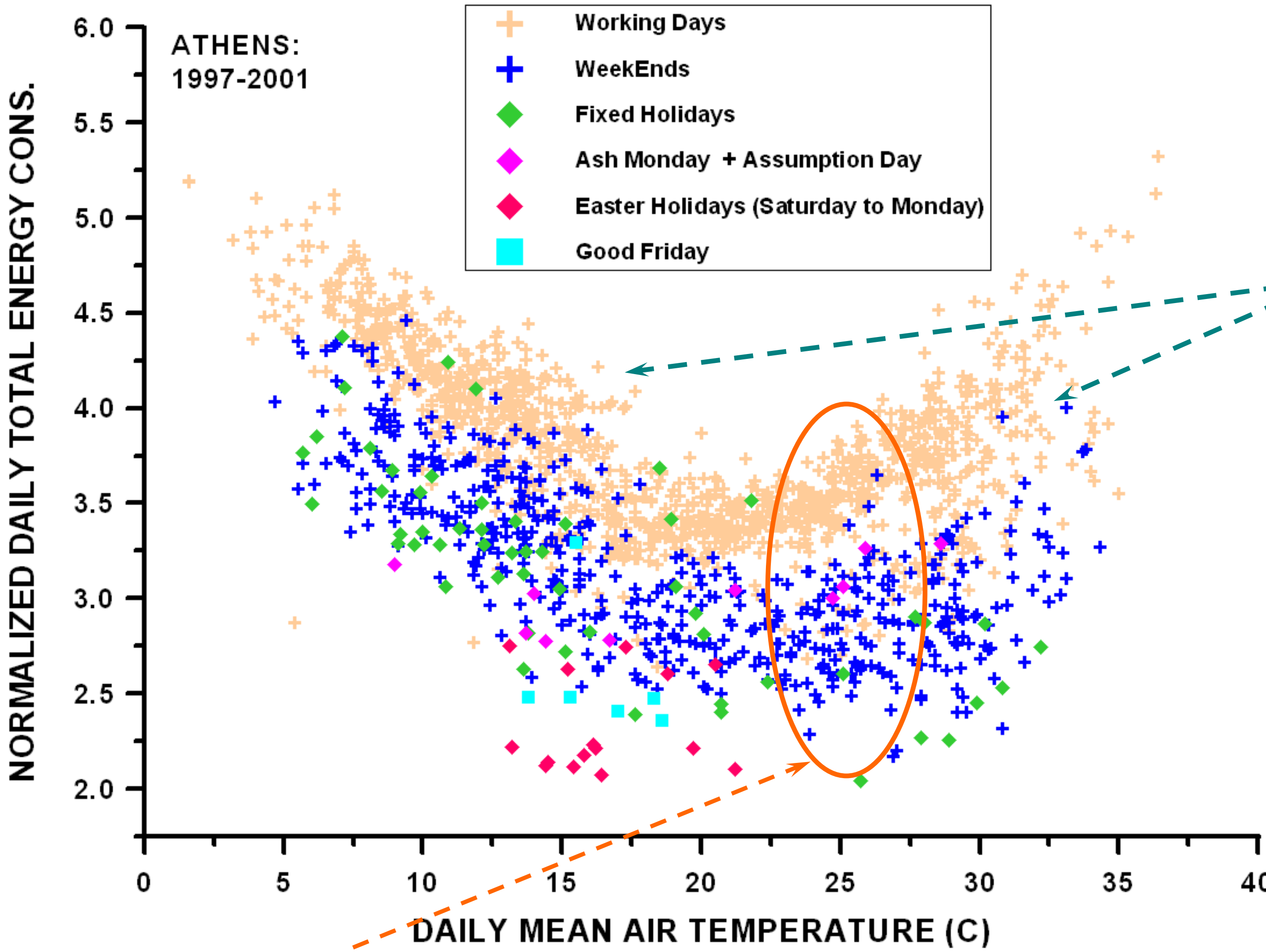


► For the calculation of excess deaths, we have used the mean of daily mortality for each summer month, for the period of1992-2006

► Heat-related deaths are not discernible below 34°C

► Substantial heat-related deaths occur at higher temperatures both from moderate and extreme heat

Energy Consumption



The relationship between energy consumption and air temperature is NOT linear.

On the contrary, presents two maxima and one minimum around **22ºC**.

However, there are certain limits beyond which energy consumption does not increase further.

Around **22ºC** there exists an area where energy consumption shows no sensitivity to air temperature. Outside this area, consumption increases with the increase or decrease of air temperature (space-heating/cooling needs).

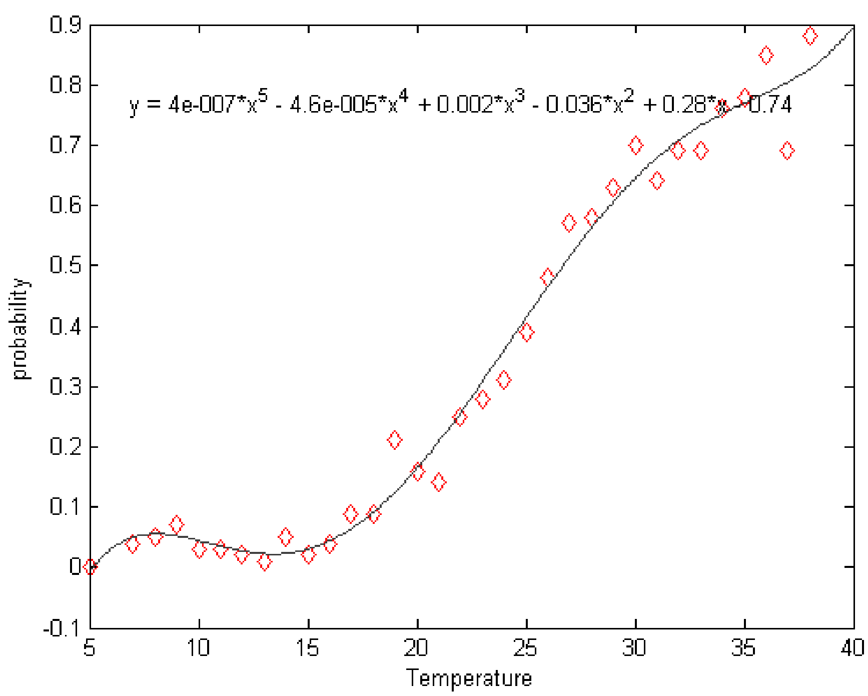
Air pollution: Ozone exceedance days

Probability of ozone exceedance with temperature

➢it is obvious that ozone exceedance days begin to appear after the threshold temperature of 18°C

Number of ozone exceedance days for each year using the E.U directives

➢the number of ozone exceedance days varies from 30 to 90



Summary table of vulnerability indicators to current climate

Key impacts indicator	Climate hazard indicators	Vulnerability indicators	System thresholds	Current impacts
Fire Weather Index	Maximum temperature Relative Humidity Wind Precipitation	Fire danger risk	Threshold for the daily fire occurrence is FWI > 15	Fire risk increases significantly with FWI>30
All-cause daily death rate	Very hot days	Human health	Very hot days threshold = 34°C	Heat-related deaths increase exponentially > 34°C.
Electricity consumption	Temperature Heating Degree Days Cooling Degree Days	Energy consumption	Minimum energy consumption occurs around 22°C	Energy demand peaks in winter and summer and during weekdays.
Air pollution	Temperature	Ozone exceedance	Threshold for ozone exceedance days is T > 18°C	The annual number of ozone exceedance days ranges from 30 to 90

Indicator linkages for Athens